THE EFFECT OF CORN GLUTEN FEED ON PERFORMANCE AND CARCASS CHARACTERISTICS OF FEEDER LAMBS

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KENDALL LYNN CAPOTE

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KENDALL LYNN CAPOTE

APPROVED:

Cody B. Scott

Michael W. Salisbury

Gil R. Engdahl

Kirk W. Braden

Adam G. Parker

June 12, 2013

APPROVED:

Dr. June H. Smith
Interim Dean of the College of Graduate Studies

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ABSTRACT

The by-product corn gluten feed can be utilized in sheep finishing diets as an alternative energy source. The objective of this study was to determine if corn gluten feed consumption affected growth rates, carcass characteristics, and meat quality of lambs. 80 Rambouillet lambs were randomly assigned to a group pen and allocated to one of four treatment diets containing different concentrations of corn gluten feed (0-10-20-30%). Average daily gain fluctuated by date and treatment by date ($P<0.05$) but was similar among treatments ($P>0.05$). Control group individuals consumed more than 20% and 30% corn gluten individuals ($P<0.05$). Feed efficiency was not different between treatment groups ($P<0.05$). At 24h postmortem, live weight, hot carcass weight, dressing percentage, loineye area, body wall fat thickness, leg circumference, and flank streaking were evaluated; harvest date for body wall fat thickness and leg circumference differed ($P<0.05$). Loin samples were then cooked and evaluated for sensory attributes, which were similar between treatments ($P<0.05$). The results of this study indicate that livestock producers can effectively use corn gluten feed as a component of lamb finishing diets without producing adverse effects on gain or carcass quality.

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INTRODUCTION

Modern ruminant production has become increasingly affected by current economic trends. In recent years, dramatic increases in the price of feedstuffs caused by competition for human consumption, increased ethanol production, and decreased feed availability because of environmental conditions such as drought have caused a shift toward a more heavy reliance on roughage feed sources (Ensminger 2002). Feed accounts for 50% to 75% of total production costs in the livestock industry, making it one of the largest expenses for producers (Kellems and Church 2002). As the land available for agricultural production is decreasing, and the price of feed inputs increasing, it has become more important for producers to understand the potential value of utilizing byproducts as part of a feeding program (Kellems and Church 2002). The expansion of the corn milling industry will continue to increase the production of byproducts, increasing their availability as feedstuffs for the livestock industry (Loza et al. 2009).

Corn gluten feed (CGF) is a quality byproduct feed that has been utilized in both the beef and dairy industries (Blasi et al. 2001). Corn gluten feed is a byproduct of the corn milling industry achieved through production of artificial sweeteners such as high fructose corn syrup (Ham et al. 1995). Wet corn gluten feed (WCGF) appears superior in nutritional quality when compared to dry corn gluten feed (DCGF), but DCGF may be more practical for producers because of decreased transportation costs, increased ease of handling, and the ability to store the product for longer periods of time prior to use (Blasi et al. 2001).

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There is limited information regarding the use of CGF in the sheep industry, but success of application in cattle warrants the need for additional research in this area, particularly in the use of DCGF. Cattle feedlot trials have shown net energy (NE) concentration of WCGF is equivalent to, if not more than dry rolled corn depending on the feed source (Parsons et al. 2007) and that DCGF can be replaced at up to 50% of the diet without having negative effects on gain of cattle (Kampman and Loerch 1989). Given that corn gluten feed is cheaper per ton compared to some other feed sources; this could mean potentially major feed cost savings for sheep producers.

Additionally, there is some evidence to support that utilization of corn gluten feed may be correlated to increased measures of carcass quality including increased hot carcass weight, dressing percentage, and quality grade of cattle fed WCGF finishing diets (Parsons et al. 2007). Conversely, others have reported negative associative effects or no effect on carcass quality, indicating that more study is needed in this area. Consequently, this study will look at the effects of feed intake and dietary level of DCGF on feeder lamb performance, carcass quality, and product sensory attributes.

OBJECTIVES

The objectives of this study were to:

1 determine if dry corn gluten feed consumption affects growth rates and carcass characteristics in feeder lambs, and

2 determine if dry corn gluten feed consumption affects meat quality.

LITERATURE REVIEW

In today's meat industry, many sheep are weaned with an average body weight of 40-50 kg and finished on high energy diets in a dry lot setting until they reach a market weight of 58 – 82 kg (USDA 2013). The main purpose of finishing lambs in this manner is because lamb finished on high concentrate diets often exhibit higher rates of gain and intramuscular fat when compared to grass fed lambs, resulting in increased tenderness and a more juicy meat product (Priolo et al. 2002). Given that fattening is typically achieved through the utilization of high energy feeds such as grains, it is important for producers to be aware of potential increased input costs from feed as compared to pasture production. The increased availability of byproduct feeds, particularly from the corn milling industry provides an opportunity for livestock producers to maximize efficiency while keeping costs as low as possible. Corn gluten feed (CGF) is a byproduct feed that has received increasing attention because of its ability to produce similar gains to conventional energy feeds with less incidence of digestive upset in the cattle feedlot industry (Ham et al. 1995). While utilizing CGF may not eliminate acidosis in the feedlot, it has been shown to decrease the total length of time that animals are exposed to aversive postingestive feedback, which can potentially create changes in intake, gain, and feed efficiency (Krehbiel et al. 1995).

Corn gluten feed is the result of the wet milling process which consists of preparation and steeping, germ separation, grinding and screening, and starch separation and conversion (Blasi et al. 2001). The end product is often composed of about 2/3 corn bran and 1/3 steeping liquor. Steep liquor content is important because it contributes almost 65% of the protein in CGF and can affect overall nutrient content of the feed if included at varying levels (Cordes et al. 1988).

Corn gluten feed can be fed in either wet or dry forms. Wet corn gluten feed (WCGF) is the direct result of the corn milling process, whereas dry corn gluten feed (DCGF) must be dried, ground through a mill, and pelleted (Blasi et al. 2001). The majority of current research has been completed utilizing WCGF, and results seem to indicate that nutritional quality is somewhat superior when compared to DCGF, most likely because of increased particle size associated with a slower passage rate through the digestive system of livestock (Ham et al. 1995). However, WCGF may not be a viable option for feedlots or preconditioning operations as mold begins to develop on the surface approximately 5-8 days after delivery (Firkins et al. 1985). Given the lower transportation costs and increased storage capabilities associated with DCGF, it may be a more cost effective alternative feed source, particularly if animal gains meet expectations. Unfortunately, it is unknown if DCGF will result in similar gains and carcass characteristics as WCGF.

Studies using WCGF in cattle have shown it has similar energy values to dry rolled corn (DRC) in finishing diets, and potentially higher net energy than dry rolled corn in receiving diets when metabolizable protein (MP) requirements are met (McCoy et al. 1998). Both DCGF and WCGF have been shown to have positive effects on organic matter (OM), neutral detergent fiber (NDF), and acid detergent fiber (ADF) digestion when compared to DRC. This often results in more positive effects on gain when utilized as part of a pasture supplementation program because CGF does not limit forage dry matter (DM) digestion as typically seen with corn supplementation (Hannah et al. 1990).

In addition to providing energy, corn gluten feed is also a source of highly degradable fiber which may reduce negative associative effects such as acidosis when utilized in combination with high concentrate feedstuffs. This has been indicated by increases in intake, gain, and efficiency observed in animals eating CGF compared to animals eating the control diet (Ham et al. 1995). Corn gluten feed is also higher in crude protein (18% CP) when compared to dry rolled corn (9% CP), thus replacing a portion of the corn in the ration may decrease the need for additional protein sources, thereby further reducing feed costs (Noble Foundation 2012).

In some cases, increasing the amount of CGF in the ration may have had direct effects on carcass quality; however, the results vary widely across studies. For example, the addition of WCGF in beef cattle rations was shown to have no effect on yield grade or quality grade (Ham et al. 1995), decrease quality grade and yield grade when compared to DRC (McCoy et al. 1998), and increase quality grade and yield grade when compared to DRC (Parsons et al. 2007). These contradictions suggest that additional and more specific research is needed to determine true effects on carcass characteristics.

Based on previous research, more study is needed to determine the interactions between corn gluten feed and sheep performance. Positive results in other ruminant studies indicate that the addition of CGF to sheep diets is a viable option to decrease input costs while maintaining productivity. Looking at alternative sources of corn gluten feed with increased longevity and practicality may be beneficial as availability of this byproduct continues to increase. Additionally, further study into potential increases in carcass merit and changes on product sensory attributes may eliminate some of the unknowns associated with use of this product.

MATERIALS AND METHODS

For this study, 80 Rambouillet feeder lambs (6 months old, less than 36 kg) were randomly assigned to one of four treatments (20 lambs/treatment). Prior to being placed on this trial, the animals were housed at the Angelo State University Management, Instruction, and Research (MIR) Center in San Angelo, Texas where they were hand-fed the control diet (Table 1) for a period of 14 days for adjustment. During the adjustment period, lambs were fed accordingly in order to maintain body weight (NRC 2007) and provided with access to ad libitum fresh water.

Each lamb was randomly assigned to a group pen by ear tag number; with 4 animals per pen and 5 pens per treatment. The treatment diets included the base diet with 0% corn gluten feed (control), base diet with 10% corn gluten feed, base diet with 20% corn gluten feed, and base diet with 30% corn gluten feed (Table 1). All rations were formulated to be both isocaloric and isonitrogenous.

Corn gluten feed was purchased directly from Hi Pro Feeds in Comanche, Texas and all feed was mixed in the Angelo State University feed mill. Feed was mixed and distributed weekly in self feeders and weekly refusals collected to monitor consumption rates. Individual animal weights were recorded every 14 days in order to monitor rate of gain and feed efficiency. The first 40 lambs that reached the target weight of 59 kg were humanely harvested to established Angelo State University Food Safety and Product Development Laboratory guidelines (ASU 2007). Twenty one lambs were harvested on the first harvest date and 19 were harvested two weeks later.

Table 1: Ration ingredients and nutrient content for control and treatment diets

	Ration (% Dry corn gluten feed)			
	0	10	20	30
Ingredients (% As Fed)				
Milo	31.3	33.0	33.0	33.0
Alfalfa	19.3	12.5	10.0	6.3
Cotton Hulls	25.0	12.5	18.8	15.0
Cottonseed Meal	10.0	7.5	6.3	5.0
Cane Molasses	3.3	3.3	3.3	3.3
Premix	2.5	2.5	2.5	2.5
Soybean Meal	8.8	8.8	6.3	5.0
Corn Gluten Feed Pellet	0.00	10.0	20.0	30.0
Nutrients (As Fed)				
Crude Protein	16.5	16.5	16.2	16.3
Crude Fiber	17.5	17.7	18.1	18.4
NEg	0.86	0.86	0.84	0.83
TDN	61.1	63.4	64.5	65.9

After the animals were harvested, each lamb carcass was surface sprayed with a 2.5 % organic acid to reduce potential contamination of carcasses and measurements for hot carcass weight were recorded (ASU 2007). The carcasses were then chilled for a minimum of 24 hours in order to reach the correct internal temperature (<7^{o}C). Following the 24 hour cooling period, the carcasses were evaluated and measurements recorded for flank streaking as well as leg circumference, body wall, loineye area, and back fat in order to accurately analyze for differences by treatment group in yield grade and carcass quality (USDA 1996). The carcasses were then fabricated and the lamb loin (NAMP #232A-Lamb Loin, Block Ready, Trimmed) was used to complete the remainder of the study. The loin was serially sliced beginning at the anterior end into 2.54 cm chops. Chops 1-3 from each loin were vacuum packaged and assigned to sensorial analysis. Vacuum packaged samples were then placed in refrigerated storage at 4^{o}C for 14 days postmortem aging. Following 14 days of postmortem aging, the samples were placed in frozen storage at -10^{o}C until further analysis.

Twenty four hours prior to preparation for trained sensory panel testing, the samples were thawed at 4^{o}C and chops were cut and prepared for sensory testing. Chops were cooked in a clamshell type grill (Kerth et al. 2003) to an internal temperature of 71.1^{o}C according to AMSA Guidelines (AMSA 1995). Trained sensory panelists made up of Angelo State University graduate students, faculty, and staff were asked to evaluate juiciness, tenderness, flavor, and off-flavor on a scale from 1 to 8 under IRB protocols.

During testing, random samples from each feed ration as well as corn gluten feed were collected and sent to Dairy One Lab, Ithaca, New York for nutritional analysis. Samples were analyzed for percent dry matter, crude protein, Neutral detergent fiber (NDF), Acid detergent fiber (ADF), and Total Digestible Nutrients (TDN).

Average daily gain, intake, and feed efficiency were analyzed using repeated measures analysis of variance as a completely randomized design with individual animals as the experimental units, treatments serving as the main effect and pens as replications. Carcass analysis was assessed using analysis of variance as a completely randomized design with treatment as the main effect and animals nested within treatments as replications. Means were separated using Tukey's LSD test when $P \leq 0.05$. All data was analyzed using the statistical software JMP (SAS 2007).

RESULTS

Based on comparison of means, nutritional quality was similar among treatment rations (Table 2). Intake differed ($P<0.05$) among treatments (Table 3). In addition, the treatment by week interaction differed (Figure 1). All treatments were initially reluctant to consume their respective treatment rations. Intake peaked during the middle of the study and then declined toward the end of the study as lambs approached the targeted harvest weight of 59 kg (Figure 1). Lambs fed a diet consisting of either 20% or 30% DCGF ate less feed than lambs receiving the control diet (0% DCGF) (Figure 2). Despite the differences in intake among treatments, there were no differences ($P>0.05$) in weight gain among treatments (Table 3). Likewise, average daily gain was similar among treatments (Table 3). However, treatment by day of collection differed (Figure 3).

Gain efficiency varied throughout the study ($P<0.05$ treatment x week interaction), but was highest at the beginning of the study (0.2 kg $^{-1}$) and lowest at the end of the study (0.1 kg $^{-1}$) (Figure 4). Even so, there was no difference between treatment groups for gain efficiency (Table 3).

Carcass characteristics including live weight, hot carcass weight, dressing percent, loineye area, body wall fat thickness, and leg circumference were similar ($P>0.05$) among treatments (Table 4). No difference by harvest date was observed for live weight, hot carcass weight, dressing percent, or loineye area, however a significant difference ($P<0.05$) was observed for both body wall thickness and leg circumference. Sensory data for loin chops such as cooking loss, initial and sustained juiciness, initial and sustained tenderness, flavor intensity, and off flavor, were also similar among treatments (Table 5).

Table 2. Mean nutrient content of treatment and control diets containing varying levels of DCGF determined by laboratory nutritional analysis. All diets were formulated to be isonitrogenous and isocaloric.

Nutrients (% As Fed)	Percent DCGF in the Diet			
	0	10	20	30
Dry Matter (DM)	90.4	90.8	90.2	89.8
Crude Protein	16.4	16.7	17.2	18.5
Neutral Detergent Fiber (NDF)	38.5	34.3	28.3	31.2
Acid Detergent Fiber (ADF)	27.2	24.0	18.8	15.3
Total Digestible Nutrients (TDN)	66.7	68.0	69.7	68.3

Table 3. Treatment means ±SEM for average daily gain, intake, and feed efficiency for lambs fed diets with varying levels of DCGF. The amount of DCGF varied from 0 to 30%. All diets were isonitrogenous and isocaloric.

Performance Data	Percent DCGF in the Diet				
	0	10	20	30	SEM
Average daily gain (kg)	0.32^{a}	0.33^{a}	0.34^{a}	0.32^{a}	0.02
Intake ($g \bullet kg^{-1}$ BW)	17.3^{a}	16.0^{ab}	15.5^{b}	15.0^{b}	0.39
Gain Efficiency (kg gain $\bullet$ kg^{-1})	0.14^{a}	0.15^{a}	0.16^{a}	0.15^{a}	0.01

^{ab} Treatment values within rows with the same superscript do not differ (P>0.05)

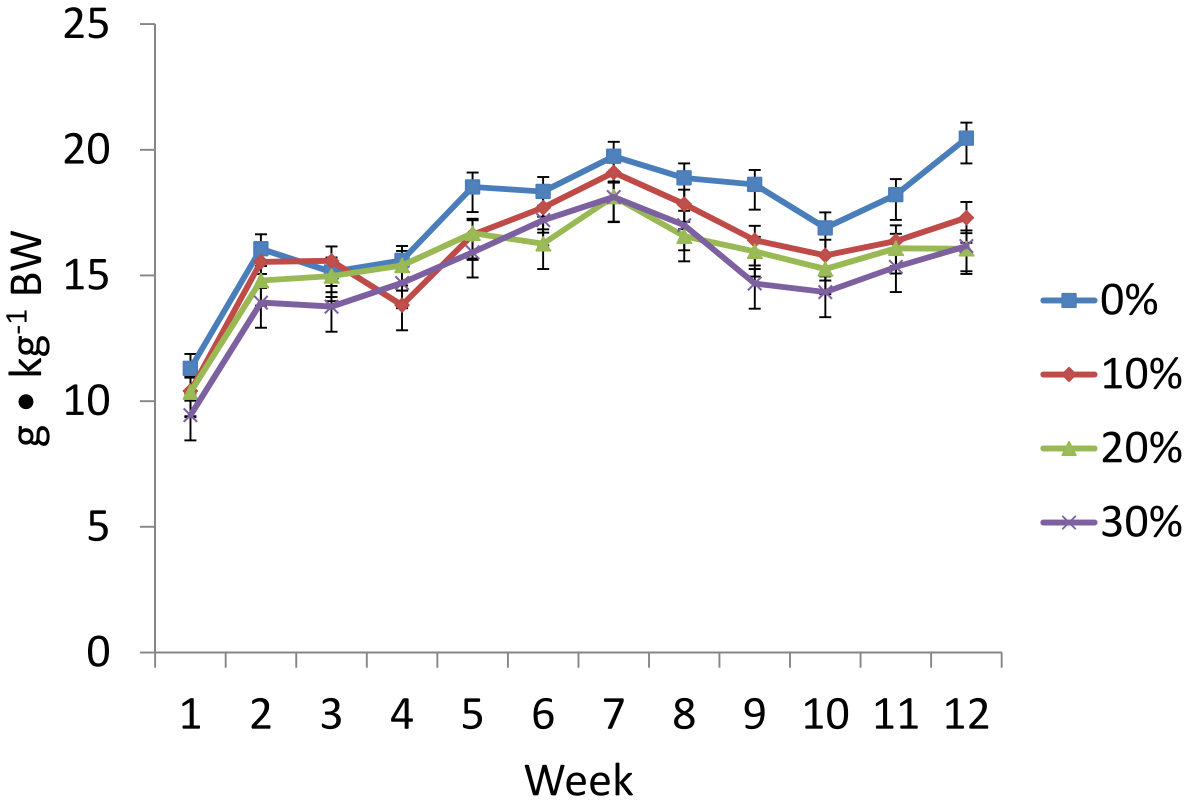
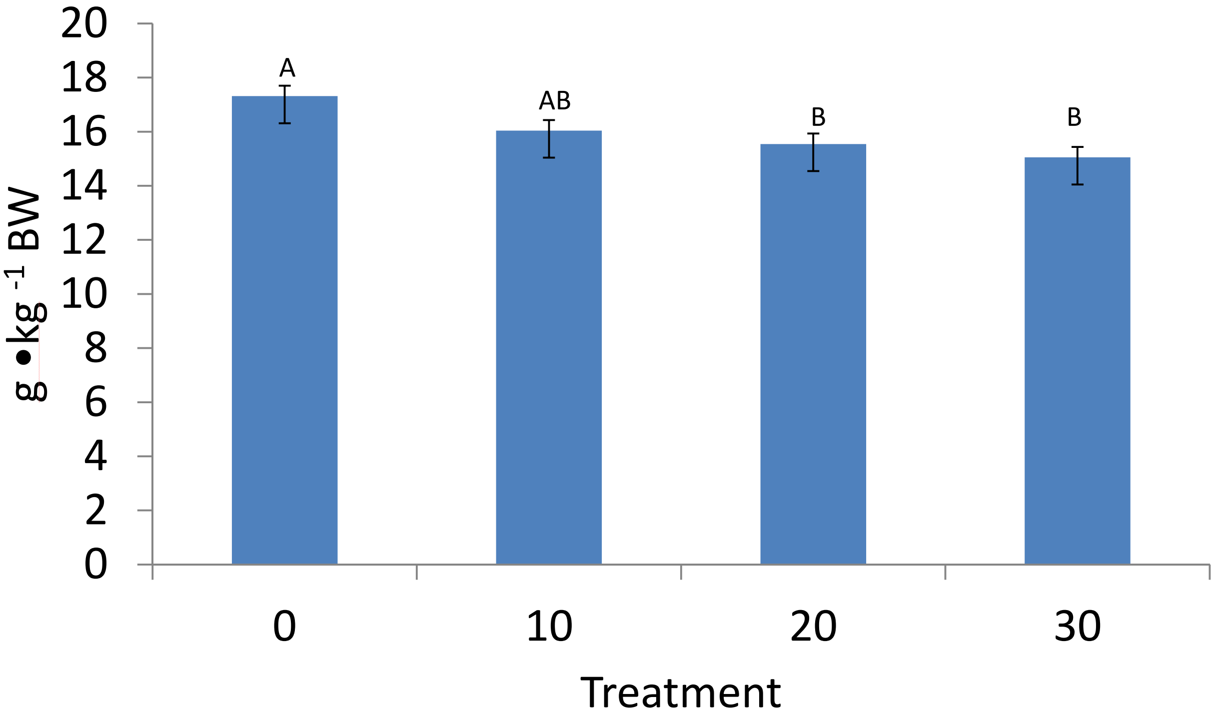


Figure 1. Intake means ±SEM by week among treatments (treatment x week interaction was significant at P<0.05) across the 84 day finishing period when sheep were fed diets containing varying levels of DCGF.



[ab] Treatment values with the same superscript do not differ (P>0.05)

Figure 2. Mean intake and standard error of treatment diets containing 0, 10, 20, or 30% DCGF fed to lambs over the 84 day finishing treatment.

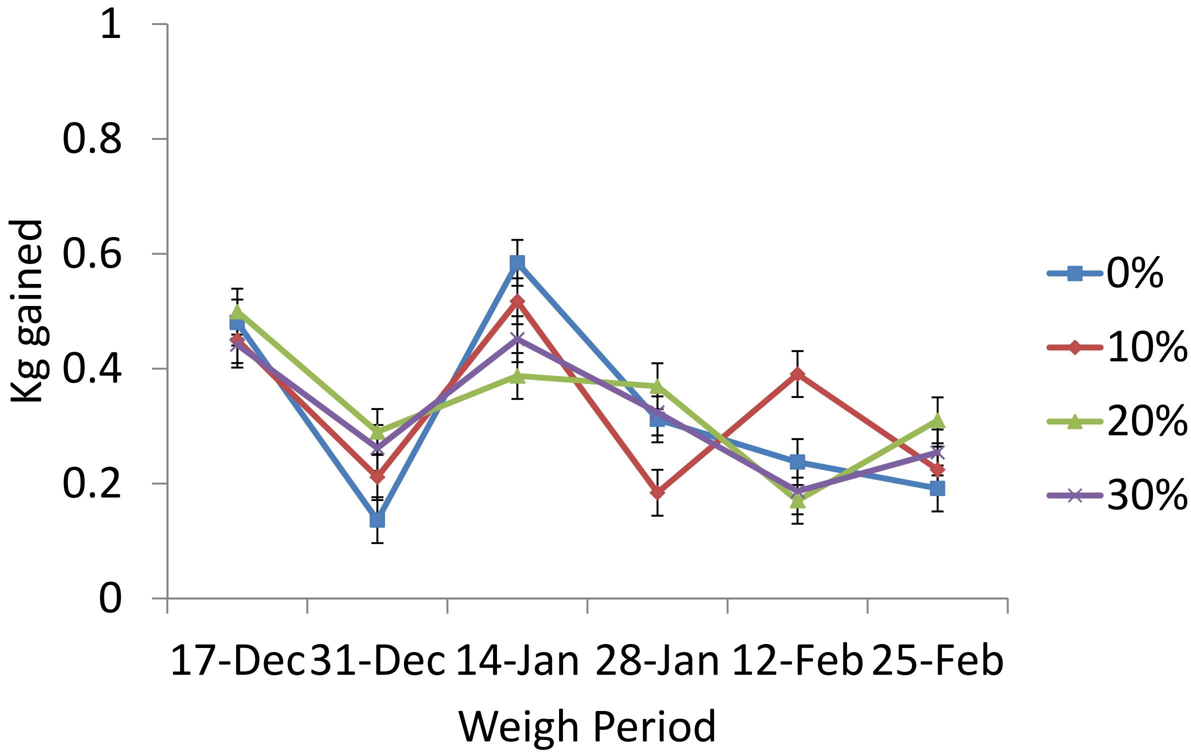


Figure 3. Average daily gain means ±SEM among treatments for each biweekly weigh period (treatment x date interaction was significant at $P<0.05$) across the 84 day finishing trial when sheep were fed a diet consisting of 0, 10, 20, or 30% DCGF.

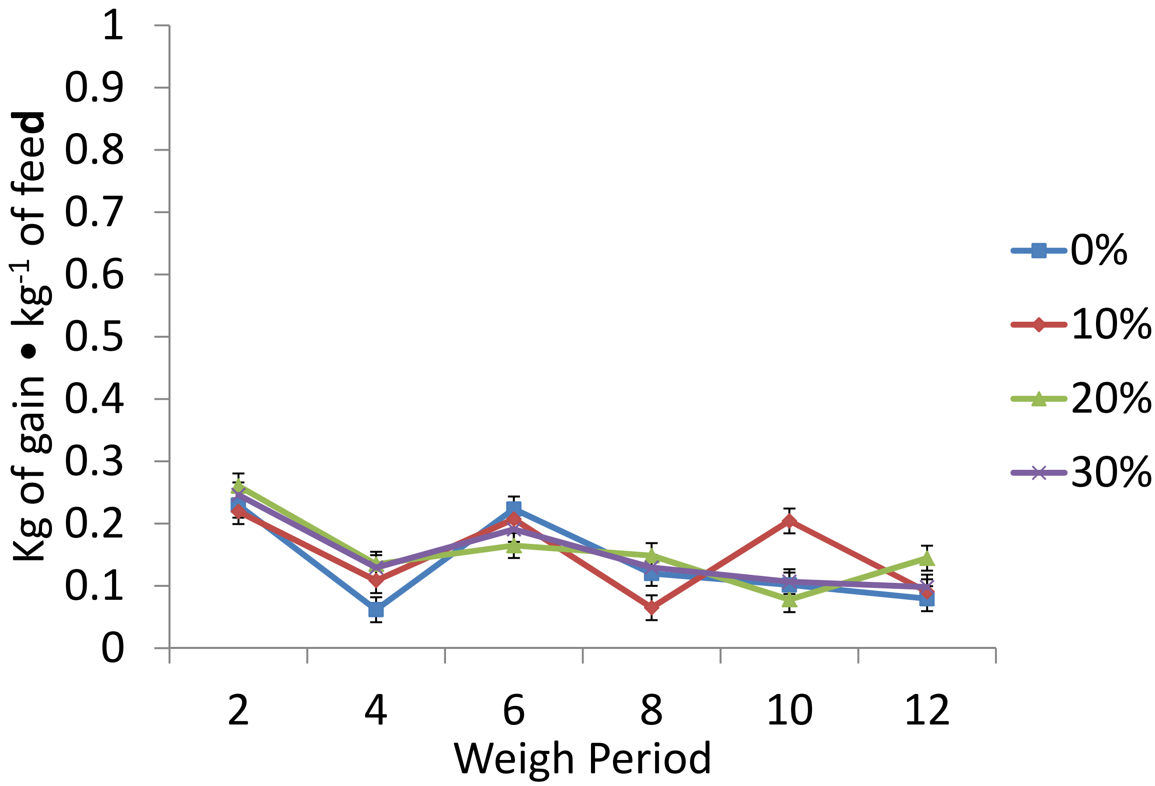


Figure 4. Gain efficiency means ±SEM by week (treatment x week interaction significant at P<0.05) of Rambouillet wether lambs for the 84 day treatment period among treatments containing varying levels of DCGF.

Table 4. Carcass characteristics means ±SEM among treatments for lambs fed diets with varying levels of DCGF. The amount of DCGF varied from 0 to 30%. All diets were isonitrogenous and isocaloric.

Carcass characteristic	Percent DCGF in the Diet				
	0	10	20	30	SEM
Live weight (kg)	52.5	53.0	54.1	53.6	0.08
Hot carcass weight (kg)	29.4	30.0	29.4	30.0	0.55
Dressing percentage (%)	55.7	56.4	54.2	55.9	0.76
Backfat thickness (cm)	0.6	0.6	0.6	0.5	0.06
Yield grade	3.0	2.8	2.7	2.4	0.26
Loin eye area (cm)	3.8	3.5	3.6	3.8	0.19
Flank streaking	473.4	474.3	495.6	436.0	38.36
Body wall thickness (cm)	1.9	2.1	1.6	2.0	0.14
Leg circumference (cm)	67.9	67.8	67.7	68.1	0.64

Table 5. Loin chop trained sensory means ± SEM for Rambouillet wethers fed different concentrations of DCGF (0, 10, 20, or 30% of the diet). All sensory attributes were assessed on a scale of 1 (poor) to 8 (excellent).

Sensory Attribute	Percent DCGF in the Diet				
	0	10	20	30	SEM
Loin chop					
Cooking loss (g)	65.5	64.5	65.0	64.3	4.21
Initial juiciness	5.9	6.0	6.0	5.9	0.16
Sustained juiciness	6.1	6.3	6.3	6.1	0.19
Initial tenderness	6.0	6.2	6.4	6.1	0.13
Sustained tenderness	6.2	6.4	6.4	6.2	0.17
Flavor intensity	5.9	6.1	6.0	6.0	0.13
Off flavor	4.0	4.0	4.0	3.9	0.02

DISCUSSION

Results of the study illustrate that there was no difference in average daily gain of sheep consuming a diet consisting of 0, 10, 20, or 30% dry corn gluten feed. Prior to this study, little data was available regarding how dry corn gluten feed consumption would affect lamb performance, as the majority of research has been done on cattle and/or wet corn gluten feed supplementation. These results agree with Firkins et al. (1985), Ham et al. (1995), and Macken et al. (2004) who showed there was no difference in average daily gain of finishing steers as the level of DCGF or WCGF increased in corn-based diets. However, while Macken et al. (2004) also showed no difference in DMI, Firkins et al. (1985) showed decreased DMI and Ham et al. (1995) showed an increase in DMI associated with CGF, which could have had an impact on the results observed for ADG in these trials. In contrast, Kampman and Loerch (1989) found that increasing the level of dry corn gluten feed in the diet resulted in a decrease in average daily gains during a 97 day finishing period. The steers on Kampman and Loerch's study also exhibited an increase in gain when increased dry corn gluten feed was provided in the diet for a growing phase trial that occurred prior to the finishing phase trial (animals were fed the same treatment diets); it is possible that the lower gains for DCGF diets in the finishing phase could be attributed to compensatory gains for animals that consumed the control diet during the growing phase.

Average daily gain fluctuated throughout the study resulting in a difference in treatment by date of collection. The recorded average daily gain was lowest for weigh period 1 and highest for weigh period 3. Average daily gain remained high for weigh periods 2 and 4, but declined towards the end of the study for weigh periods 5 and 6. These results mirror changes in dry matter intake over the treatment period, thus differences in gains can be attributed to increases or decreases in consumption of the treatment diets. Reasons for the treatment by day of collection remain unclear, but may be in response to weekly variations among treatments for intake.

This study also indicated a difference among intake of treatment diets, as lambs consuming the 20 and 30% dry corn gluten feed diets consumed less than the control, or 0% corn gluten feed diet. This contrasts with the results from previous research completed by Firkins et al. (1985), who determined no significant difference in dry matter intake of lambs supplemented with WCGF, DCGF, or SBM on corn-silage based diets. For the lambs on this trial, gain was not recorded, so the effect of intake on gain was not determined, making it difficult to compare results accurately as rate of gain may have an effect on intake. However, two cattle finishing studies also completed by Firkins et al. (1985) showed that cattle consuming DCGF had higher dry matter intake than both WCGF and SBM supplemented diets when cattle had either increased or similar average daily gains. Similar research conducted by Farran et al. (2006) and Macken et al. (2004), showed that DMI of steers consuming WCGF increased subsequently as the level of co-product in the diet was increased.

A digestibility study completed by Bowman and Paterson (1988) also showed increased intake of WCGF compared to other treatment diets, despite the fact that there was no significant difference in total tract or ruminal digestibility for corn and soybean meal or dry, wet, or ensiled corn gluten feed. However, a similar study conducted with lambs found that while lambs provided with corn gluten feed in the diet also showed no difference in total tract digestibility, ruminal DM digestibility decreased (Bowman and Paterson 1988). This could potentially be due to increased microbial efficiency with high fiber CGF diets (Bowman and Paterson 1988). Provenza (1995) suggests that livestock reach satiation more quickly when nutritional requirements are met, thus intake could have decreased as needs for microbial protein were met by higher concentrations of corn gluten feed in the diet. Additionally, Bowman and Paterson (1988) found that the amount of acid detergent fiber (ADF) digestion that occurred postruminaly increased when corn gluten feed was provided in the diet. This agrees with Firkins et al. (1985), who found that while DMI was similar for lambs fed diets containing DCGF, WCGF, or corn silage, ADF digestibility decreased when DCGF was utilized in the diet. These results suggest that the cellulose in dry corn gluten feed may be less readily digested than in other feedstuffs and it is highly possible that the drying process utilized in the manufacture of DCGF may alter the cellulose structure (Firkins et al. 1985). If the digestibility of DCGF was decreased, it is possible that passage rate of DCGF may have also been affected causing animals to alter their rate of intake. Staples et al. (1984) suggests that animals may decrease consumption of feeds with high levels of fiber to improve feed digestion.

In addition to the above hypothesis, the 20% and 30% dry corn gluten feed diets utilized in this trial exhibited higher levels of both crude protein and total digestible nutrients (Table 2) compared to the control and 10% DCGF diet when proximate analysis of treatment diets was completed. Higher nutrient content could have caused lambs to meet the same nutritional requirements while consuming less feed, thus resulting in a decreased DMI with similar ADG as observed in this study.

As mentioned previously, intake of treatment diets fluctuated similarly to average daily gain and differences were observed for both week of data collection and treatment by week. Lambs exhibited lower intake initially, most likely due to reluctance to consume a novel food as lambs had never been previously exposed to corn gluten feed. The control and 10% treatment diets were more similar to the ration lambs were provided with during the 14 day adjustment period, which may also explain some of the differences in intake patterns as animals are more likely to consume familiar foods. It is also possible that lamb consumption may have decreased initially in response to the self-feeders, as it may have taken time to learn how to eat out of these feeders and/or determine an order of dominance in terms of eating behavior. Intake peaked during the middle of the study, as lambs were actively growing and putting on pounds of gain. Toward the end of the study intake tended to decrease, which may have been a result of declining nutritional requirements as lambs began to reach market weight and put on fat.

The results for gain efficiency in this study indicated no significant differences by treatment. These results disagree with Ham et al. (1995) who found that adding 70% DCGF to the diet produced a decrease in feed efficiency compared to dry rolled corn when cattle showed no significant difference in DMI. Consequently, WCGF produced similar feed efficiency compared to DRC, but cattle consuming WCGF exhibited an increase in ADG (Ham et al. 1995) which was not the case in this trial. According to Kampman and Loerch (1989), cattle who exhibited a decrease in DMI when DCGF was included in the diet from levels ranging from 40-80% subsequently had increased gain efficiencies. Similarly, McCoy et al. (1998) showed that cattle consuming WCGF at 52% of the diet were more efficient when DMI was less and ADG was similar to the control diet of dry rolled corn. While intake decreased as a result of including DCGF at levels 20% or higher in the diet in this study, changes in consumption pattern were not large enough to cause subsequent changes in gain efficiency. Previous studies indicate that including corn gluten feed in diets at higher levels may create more extreme differences in feed: gain, thus it may be possible that if DCGF had been included in the diet at rates of 40% or more it may have produced similar results in this study.

A survey completed by Vasconcelos and Galyean (2007) showed that anywhere from 13.5% to 0% roughage is included in feedlot diets depending on the time of year. Farran et al. (2006) suggested that including highly digestible fiber sources such as WCGF in the diet may decrease the need for high inclusion rates of alfalfa or other roughage sources. This study showed that as the level of alfalfa hay in the diet was increased when 35% WCGF was provided, the dietary energy value of the alfalfa hay may have decreased (Farran et al. 2006). In response to this, cattle consuming a diet containing 35% WCGF and 0% alfalfa hay exhibited a 4.4% gain efficiency compared to diets containing 35% WCGF and either 3.75% or 7.5% alfalfa (Farran et al. 2006). For this particular study alfalfa was included in the diet at levels ranging from 15.7% (control) to 5.5% (30% DCGF) (Table 1). While diets were formulated to be both isocaloric and isonitrogenous, Farran et al. (2006) suggests that altering the level of alfalfa pellets in the diet may have potentially produced different results for gain efficiency in this study.

Again, variation occurred throughout the study for gain efficiency and significant differences were observed by week in addition to a week by treatment interaction. As with previous results, efficiency was highest in the beginning of the study and lower towards the end of the study as animals began to reach the target weight. This indicates that changes in gain efficiency during the study are direct results of changes in intake and average daily gain that occurred during the treatment period.

Measurements of carcass characteristics taken during this study revealed that inclusion of DCGF in the finishing diet of feeder lambs did not cause any changes in carcass quality. These results are similar to the findings of McCoy et al. (1998) and Ham et al. (1995) who discovered that WCGF did not affect quality grade, yield grade, or fat thickness when cattle gained similarly. Consequently, Hankins et al. (2005) discovered that while there was no difference in quality or yield grade when CGF was included as 45-50% of the diet for 186 days, final body weight and hot carcass weight were heavier for steers provided with corn gluten feed as a result of increased gains throughout the trial period. Loza et al. (2010) also determined that when average daily gain was increased in response to inclusion of 30% WCGF, hot carcass weights were greater. Increased hot carcass weights in Loza's study also contributed to increases in yield grade as well as marbling score (Loza et al. 2010). While no differences for ADG were observed for this study, since WCGF contains more net energy than DCGF in dry rolled corn finishing diets (Ham et al. 1995) it is possible that increasing the level of dry corn gluten feed in the diet could lead to increases in gain and subsequently heavier carcasses, which may also have an effect on carcass quality. Alternatively, Kampman and Loerch (1989) determined that as the level of DCGF in the diet increased from 0% to 80% hot carcass weight decreased in response to declines in both average daily gain and gain efficiency. However, these results occurred in a high moisture corn based diet as opposed to dry rolled corn as utilized in the aforementioned studies.

Differences by harvest date were observed for both body wall fat thickness and leg circumference in this study. It is likely that these results can be attributed to differences in lamb maturity as the group of lambs harvested later were two weeks older than the first group. Not only could the more mature lambs potentially be larger in size, but it is likely that lambs began to put on an increased amount exterior fat as they began to reach the target market weight.

Shahidi and Rubin (1986) suggest that feed source plays an important factor in meat flavor. However, this study found that meat products from lambs fed levels of DCGF at up to 30% of the diet exhibited no signs of a strong flavor or taste as a result of corn gluten feed consumption. Additionally, panelists determined chops had excellent ratings for both sustained and initial juiciness and tenderness, with averages of 5.95, 6.18, 6.19, and 6.31 respectively for all treatments on a scale of 1= extremely tough/dry to 8=extremely tender/juicy. These results may have occurred in response to similar carcass characteristics, but both Jeremiah et al. (1998) and McEwen et al. (2007) found that carcass characteristics and meat palatability are generally not affected by grain source at levels of high enough magnitude to make them of importance. Although no previous research has been completed with corn gluten feed in terms of sensory characteristics, Shand et al. (1997) found that the by-product feeds wet brewers grains and wet distiller's grains had no effect on sensory properties or shear values of beef, which agrees with the results found in this study.

This study indicates that lambs will gain similarly while consuming less feed when DCGF replaces an energy source in finishing diets. However, in addition to potentially decreasing feed input costs through decreasing the total amount of feed provided to livestock, substituting DCGF in the diet also decreases the total cost of the ration. By providing a ration containing 30% DCGF, livestock producers will save $6.25 per metric ton of feed as the total cost of treatment diets used in this study containing 0, 10, 20, or 30% DCGF was $332.51, $329.14, $325.77, and $326.26 per metric ton, respectively.

IMPLICATIONS

Utilizing dry corn gluten feed as an energy source in lamb finishing diets does not appear to adversely affect animal performance, carcass characteristics, or meat quality. Adding corn gluten feed to rations in this study at levels greater than 20% not only decreased dry matter intake, but also lowered the cost of rations per metric ton, which could potentially decrease feed input costs for livestock producers. Although previous research presents conflicting results; particularly in the use of dry corn gluten feed in lamb production, the literature suggests that further research is warranted to determine if including DCGF in the diet at levels greater than 30% would create more significant differences in production or carcass characteristics of lambs than were observed in this study. However, given the current high prices of corn, milo and other commonly used energy sources, increasing the level of dry corn gluten feed provides a viable option for sheep producers to maintain production values of their livestock while minimizing costs.

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VITA

Kendall Lynn Samuelson (Capote), the daughter of Bill Capote and Cindy Capote was born on June 10, 1986 in San Mateo, California. Kendall grew up in San Carlos, California where she began to develop her interest in agriculture despite being from an urban background. Upon graduation from high school, she enrolled at California State University, Chico where she completed her Bachelor of Science degree in Animal Science with a minor in Agricultural Business. While at Chico State, she was heavily involved in the professional agricultural sorority Sigma Alpha, worked at both the Sheep and Beef units, and met her husband, Patrick Samuelson. Following graduation she continued her higher education at Angelo State University to pursue a Master's degree in Animal Science. Following graduation from ASU, Kendall plans to continue her education as a doctoral student in Animal Science at New Mexico State University studying beef cattle feedlot nutrition.